Contents

• High performance FW/blanket design with SiC/SiC structure:
  – FW design characteristics
  – Blanket design characteristics
  – Design issues

• Breeding capacity of LiPb and LiSn breeders

• Sensitivity of breeding to amount of SiC structure

• Expected overall TBR and Mn for SiC system
### Preliminary Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Average OB heat flux</td>
<td>0.7 - 1 MW/m²</td>
</tr>
<tr>
<td>max OB NWL</td>
<td>7 - 10 MW/m²</td>
</tr>
<tr>
<td>max SiC/SiC temp.</td>
<td>1100 – 1400 °C</td>
</tr>
<tr>
<td>Breeder exit temp.</td>
<td>~ 1000 °C</td>
</tr>
<tr>
<td>SiC/SiC thermal conductivity</td>
<td>20 – 30 W/mk</td>
</tr>
<tr>
<td>FW location at midplane – IB, OB</td>
<td>3.5, 6 m</td>
</tr>
<tr>
<td>Top/bottom FW radii – IB, OB</td>
<td>3.5, 4 m</td>
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</table>
FW Design Characteristics

- FW design is still evolving

- FW consists of array of bundles overlapped toroidally to intercept surface heat flux

- Horizontal cross sections at midplane \((R = 6 \text{ m})\) and at top/bottom ends \((R = 4 \text{ m})\) are shown in Figs. 1 and 2

- Single FW bundle (shown in Fig. 3) consists of set of twisted tubes surrounding a straight central tube

- Breeder flows poloidally in SiC/SiC tubes.

- Tube wall is 0.3 cm thick and breeder tube diameter is 1 cm

- Number of tubes and dimensions will be optimized later

- Plasma facing FW surface needs protective coating. Few mm of SiC (or Be) coating could be sprayed on FW in factory or in-situ

- FW design is also applicable to divertor system
Fig. 1. IB or OB FIRST WALL AT MIDPLANE

Diameter = \( D \)

\[ L = \frac{3}{2} D \]
Fig. 2 OB FIRST WALL AT TOP/BOTTOM

BLANKET

Toroidal Direction

Plasma

D
Fig. 3  Bundle of Twisted Tubes

Straight Central Tube

Pitch $> 6D$
Blanket design is at an early stage of development

Currently investigating two blanket options:

- Breeder flowing poloidally in square cells
  (similar to ARIES-ST and Tauro designs)

- Stagnant breeder pool with:
  - large bubbling of helium for tritium extraction
  - coolant flowing in SiC channels for heat removal.

No decision has been made yet on preferred option.
Expected values

- Heat flux handling capacity  > 1 MW/m²
- Thermal conversion efficiency  50 – 60%
- Max temp. of SiC/SiC structure  1400 °C
- Max. temp. of breeder  1000 °C
- Optimum FW composition/dimension
- FW spray coating: SiC or Be
- FW outgasing
- Manifolding and attachments
- Accommodation of Kink stabilizing shell
- Blanket segmentation
- Flowing or stagnant breeder in blanket
- Compatibility of breeder with SiC at high temp.
- SiC content in blanket  10 - 20%
- IB blanket thickness  20 - 50 cm
- OB blanket thickness  50 - 80 cm
- Breeding capacity of candidate breeders
- Others?
Breeding Potential of LiPb and LiSn Breeders

- Li25Sn75 has lower breeding potential than Li17Pb83

- LiPb and LiSn with natural Li have TBR of 1.6 and 0.5, respectively

- FW/Blanket structure, penetrations, and geometry will degrade overall TBR to 1.1 or less
Breeding Capacity of LiPb and LiSn in Realistic Design

• **Starting dimension/composition:**
  – 20 cm thick IB blanket and 50 cm thick OB blanket (ARIES-RS type blanket)
  – 15% SiC structure in blanket
  – 90% enriched Li
  – 5 cm thick FW (2 cm SiC, 3 cm LiPb)

• No breeding blanket behind divertor

• Breeder-cooled divertor and HT shield

• Required TBR = 1.1

• Results:

<table>
<thead>
<tr>
<th>Breeder/structure</th>
<th>LiPb/SiC</th>
<th>LiSn/SiC</th>
<th>Li/V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(85/15)</td>
<td>(85/15)</td>
<td>(90/10)</td>
</tr>
<tr>
<td><strong>Overall TBR</strong></td>
<td>1.07</td>
<td>0.85</td>
<td>1.1</td>
</tr>
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</table>

• To increase TBR:
  – Thicken blanket
  – Reduce SiC content in blanket
  – Reduce SiC content in FW
**TBR of LiPb/SiC and LiSn/SiC Blankets**

- **LiPb/SiC** blanket satisfies breeding requirements with:
  - 40 cm thick LiPb/SiC IB blanket
  - 50 cm thick LiPb/SiC OB blanket
  - 15% SiC structure in blanket
  - 5 cm thick LiPb/SiC FW
  - LiPb/SiC blanket has ~5% excess breeding capability

- **LiSn/SiC** blanket does not meet breeding requirements. Thick blankets increase TBR to ~0.9:
  - 40 cm thick LiSn/SiC IB blanket
  - 70 cm thick LiSn/SiC OB blanket
  - 15% SiC structure in blanket
  - 5 cm thick LiSn/SiC FW
If design calls for more (or less) SiC content than 15% in blanket, LiPb/SiC blanket thickness will be used to adjust TBR to 1.1.

LiSn/SiC blanket without SiC structure has TBR of 0.95.
Sensitivity of TBR to SiC Content in FW

- SiC of FW has larger impact on breeding than SiC of blanket
- Each mm of FW SiC changes TBR by ~1%
- Lower SiC content in FW allows thinner OB LiPb/SiC blanket than 50 cm and/or higher SiC structure in blanket than 15%
- **LiSn/SiC** blanket will not breed unless SiC in BOTH FW and blanket is reduced to 1 cm.
- Is 1 cm SiC structure sufficient to support 40-70 cm thick LiSn blanket?
Conclusions

- Proposed FW/blanket design potentially offers high heat flux handling capability and high thermal conversion efficiency

- LiPb/SiC blanket satisfy breeding requirements (TBR = 1.1) with excess breeding capability

- LiSn/SiC will not meet breeding requirements unless SiC structure is limited to 1 cm or less in both FW and blanket

- Beryllium multiplier could enhance breeding potential of LiSn/SiC blanket

- Overall Mn will not exceed 1.1 for both breeders, meaning larger machine than ARIES-RS (Mn = 1.2) for same net output power.